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Short Term Histological Changes in the Palatal Sutures and the Periodontal Ligaments Resulting from Rapid Palatal Expansion in the Rhesus Monkey

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SHORT TERM HISTOLOGICAL CHANGES IN THE PALATAL SUTURES AND THE PERIODONTAL LIGAMENTS RESULTING FROM RAPID PALATAL EXPANSION IN THE RHESUS MONKEY

BY

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Dedicated

to

My mother, Mrs. Michael T. Reardon, in appreciation for her many sacrifices which have made my education possible.

VITA

Timothy Patrick Reardon was born in Omaha, Nebraska on April 28, 1946. He graduated from Creighton Preparatory High School in Omaha in June, 1964.

After studying a pre-dental curriculum at Creighton University, he entered Creighton University School of Dentistry in September, 1967 and was graduated with the degree of Doctor of Dental Surgery in June, 1971.

Upon completing his dental education, Dr. Reardon served in the United States Army as a captain in the Dental Corps and was a staff member at William Beaumont General Hospital in El Paso, Texas for two years.

After leaving the service, he practiced general dentistry in Los Angeles, California until 1974.

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INTRODUCTION

Maxillary width deficiencies may be successfully corrected through a procedure called rapid expansion of the midpalatal suture using a fixed acrylic appliance.

The dentition erupts into an environment completely dominated by a muscular system which dictates individual tooth position. In patients demonstrating severe maxillary constriction, any conventional orthodontic expansion procedures, either fixed or removable, only encourage relapse since they often tip the teeth beyond the boundaries dictated by the surrounding musculature. Rapid maxillary expansion is an orthopedic and orthodontic procedure in which the teeth themselves are displaced only slightly in their alveoli while the maxillary bones with their attached musculature are separated. Thus, according to Zimring and Isaacson (1965), the teeth occupy their same relative position over the basal bone, and will be subjected to the same muscular influence, enhancing stability and the success of treatment.

The increasing use of this procedure necessitates the need for more knowledge with regard to its effects on the palatal sutures and the dentition.

The main objective of this study was to evaluate any histological changes as a result of palate splitting therapy in the palatal sutures and the periodontal ligaments of teeth that served as abutments for fixed expansion appliances. The expansion procedures were performed on four young rhesus monkeys in the same manner as they are carried out in human patients. The tissues were evaluated for possible alterations in cellular proliferation and cell density after ten days of expansion.

REVIEW OF THE LITERATURE

E.H. Angell was the first to publish an article on the subject of rapid maxillary expansion in 1860. He claimed that he had opened the midpalatal suture of a fourteen year old girl with an anterior cross-bite "to widen the jaw and expand the maxillary arch (with) a jackscrew apparatus..... a screw threaded in opposite directions to engage nuts likewise threaded. These nuts were attached to metal collars or clasps on opposite side of the upper jaw."

Although this was before the advent of roentgenology, Angell rightly reasoned that the resulting increased width was due to the opening of the midpalatal suture. His exact word were, ".....at the end of two weeks the jaws were so widened as to leave a space between the front incisors, showing conclusively that the maxillary bones had separated," (Biederman, 1973).

By the turn of the century, Nelson Black (1909) and many others advocated the use of palatal expansion as a possible relief for constricted nasal passageways, but their opinions were based mostly on subjective findings.

But this procedure was almost completely abandoned in the United States by 1929 due to the widespread acceptance of the functional concept of development. Some of the more

notable men who felt indifferent to palate splitting were: Case (1893), Angle (1910), Ketcham (1912), and Dewey (1914); and they were primarily responsible for its discontinuance in this country. They felt that they could gain all the benefits inherent to palate expansion by gently moving the teeth into their proper position by conservative orthodontic methods, and if vigorous function followed, bone would grow to support the teeth, (Haas, 1961).

This whole concept of functional development went unchallenged until 1938 when Brodie and the staff at the University of Illinois Orthodontic Department published findings of the x-ray appraisal of treated orthodontic cases. It was seen that all actual bone changes were restricted to the alveolar process. Supporting bone was not changed, and there could be no accompanying increase in width of the nasal passage by conventional orthodontic means.

European orthodontists, however, continued to use palatal expansion, and Korkhaus probably was responsible for reintroducing the procedure to this country in 1956.

Krebs (1958) used metallic implants to study the amount of palate expansion. He placed three implants on either side of the infrazygomatic ridges and one or two in the alveolar bone lingually to the canines. Changes in width were registered a) after expansion; b) after retention with the fixed

appliance; and c) after eight months retention with a removeable plate. In the one case that he wrote about it was seen that the increase in width of the dental arch during active treatment was about twice that of the basal maxillary segments, while the increase of the alveolar arch lingually to the canines was almost midway between these two. During the retention period the width of the dental arch was maintained, but the distance between the right and left side of the alveolar arch and the basal maxillary segments showed a tendency to lessen.

The greater increase between implants in the alveolar arch than between implants in the infrazygomatic ridges was probably due to a rotation of maxillary segments. There was a greater increase in width in the lower segments than in the upper segments of the maxilla. Also the increase was greater anteriorly than posteriorly.

When Debanne (1958) did palate expansion on cats, he found that their midpalatal sutures were opened. Histologic sections showed that there was a concomitant deposition of new bone. The opening was greater in the anterior region and no opening was apparent at all in the more posterior regions of the palatine bones. This was explained by the fact that the boney configurations of the midpalatal edges of the maxillary bones were closely interdigitated, whereas the edges of the premaxillary bones ran parallel to each other. Therefore

it would take more force to open the midpalatine suture than the premaxillary suture.

Debanne found the new bone formed in the suture opening was of the bundle type. Also tooth movement accompanied palatal opening, with deposition of bone on the tension side and resorption on the pressure side.

In 1961 Haas split the palates of pigs with an acrylic plate with a jackscrew. He showed that there was a significant change in the maxillary arch while at the same time there was an increase in the intranasal cavity. The mandibular dental arch was also expanded slightly. From the finding in this animal study, he felt that maxillary suture splitting would be of benefit to severe mouth breathers who would be aided by anything short of resection of the nasal concha.

Haas then used this appliance on forty-five patients and examined the results. He preferred to use an acrylic body rather than an all wire framework so that much of the expanding force would be exerted against the alveolar process and base bone rather than just the teeth. Since the force of turning the screw would tend to displace the appliance, it was felt that a fixed appliance would be better than a removeable one. A removeable expansion screw appliance would primarily tip teeth laterally. The fixed appliance was such that one full turn of the screw was equivalent to an 0.8mm -

1.0 mm opening, and the screw was activated one quarter turn at a time. A string was tied around the key so that the patient could not swallow it during activations. The patient's parents were instructed to give the screw one quarter turn in the morning and one quarter turn at night. After the necessary expansion had occurred, the appliance was left in for three months as a retainer to allow bone to fill in the suture. After the three month retention with the expansion appliance, it was removed and an acrylic palate retainer was worn throughout treatment and retention.

The earliest reaction to turning the screw was a lateral bending of the arches followed by a gradual opening of the suture. The palatine processes then began to move inferiorly to cause a lowering of the palatal vault. The bracing action of the zygomatic buttresses caused the separation between the maxilla to be wedge shaped with the apex being in the nasal cavity. The mandibular teeth tended to follow the maxillary teeth out which might have been due to changes in the forces of occlusion, a lowering of the position of the tongue (because of the thickness of the appliance), and the fact that the splitting caused the attachment of the buccinator muscle to move laterally where its crushing force on the mandibular arch is diminished.

Haas (1965) found that the patients rarely complained of

pain during palatal expansion. It was shown that a gap appeared between the central incisors which was about one-half as great as the distance the screw had been opened. It was seen also that the roots of the centrals diverged a greater distance than the crowns during expansion. After the opening of the suture had stopped, the roots continued to diverge while the crowns tended to move toward the midline to their original relationship. After the crowns drifted together the roots began to move medially so that the incisors eventually resumed their original axial inclination.

Haas felt that this reaction of the central incisors was indicative of the presence of transeptal fibers. Opening the intermaxillary sutures stretched these fibers connecting the central incisors. These stretched fibers drew the crowns of the teeth back together very rapidly. Patients experienced a tenderness in these teeth even though they were usually out of occlusion and never acted upon directly by the appliance. The cycle, from the time of initial activation to the time when the central incisors returned to their original position, was completed in four to six months even with incisors spaced as much as 8mm. after appliance manipulation.

It was seen that there was calcification of the sutures in about 90 days after suture opening. It was also seen that the point A moved forward in all cases and that in one-half of

the cases it moved downward.

Haas saw that the downward and forward movement of the maxilla caused certain obvious changes in occlusion such as an opening of the bite. The cant of the occlusal plane increased, and so did the mandibular plane angle.

Palate expansion can be well used in Cl III cases. The anterior migration of the maxilla in many instances corrects the anterior cross-bite completely. If more of an antero-posterior correction is necessary, the loosened maxilla comes forward easily in response to the pull of vigorous Cl III elastics.

It would appear that with the downward and forward movement of the maxilla, Cl II cases would seemingly be made worse and Cl III cases improved. This is true but in Cl II cases the maxilla tend to recover and moves posteriorly again, whereas in Cl III cases the maxilla tends to stay forward. This is probably due to the altered forces of occulsion since the anterior crossbite is wholelly or partially corrected.

Theoretically Haas felt that the midpalatal suture could be opened as long as it remained patent.

In 1966 Starnbach et al. split the palates of monkeys. It was seen that in the control the periodontal membrane and alveolar bone appeared normal with the fibers being well oriented; whereas the animal with rapid palatal expansion had

periodontal fibers that were disorganized, with a wider membrane on the palatal side of the teeth. With animals that had longer retention after the expansion there was less of a reaction in the membrane. The facial sutures that they studied were the nasal suture, the zygomatico-maxillary suture, and the zygomatico-temporal suture. The monkeys that were subjected to splitting of the midpalatal suture showed evidence of greater cellular activity at all three sutures than did the control animal. The nasal suture showed the greatest activity. The longer the animals were in retention after expansion the less were the reactions at the suture site.

Despite the awareness of controlled force levels in orthodontics today, no data has been reported to even approximate the magnitude and duration of the forces associated with rapid expansion technique.

In 1964 Isaacson et al. embedded a dynamometer in the acrylic appliance. They conducted the experiment on five patients. The response of the buccal quadrants to rapid expansion differed between patients. It was shown that a single activation of the screw (0.2mm) produced from about three to ten pounds of force. Also there was the suggestion that a smaller load was produced in the younger patient as compared with the more mature patients. Since the force values recorded represent an indication of the resistance of

the facial skeleton to expansion, this finding suggests that the facial skeleton increases its resistance to expansion significantly with increasing maturity and age.

No significant changes in the force values present during the time the suture opened were apparent in this study. Isaacson thus concluded that the major resistance to rapid maxillary expansion apparently is not the midpalatal suture but the remainder of the maxillary articulations. Therefore the retention of those cases relies more probably on the creation of a stable relationship at the articulations of the maxilla and the other bones of the facial skeleton.

The limited data in his study suggests that the decay of the force immediately following an activation is rapid, but the rate of decay rapidly decreases within several minutes. Therefore it should not be necessary to wait more than five minutes between activations on the first day. And two activations on the first day would produce the maximum forces produced by two daily activations during the remainder of treatment.

Also it appears that lower loads than ten pounds may be well capable of producing equally successful clinical results.

It can be seen that with forces at what they are, the appliance would be displaced if it was removeable. And

compared with what is currently accepted as optimum force values for tooth movement, it should be concluded that inclined plane forces derived from screws are undesireable for producing single tooth movement. Also because of the high level of forces during activation, it would not be good to have an expansion screw appliance with a spring loaded expansion screw because it would necessitate frequent remaking of the appliance.

In 1968 Wertz did a study on the effects of rapid maxillary expansion on changes in nasal airflow. He showed that there was an increase but due to the non-parallel configuration of the opening, an obstruction causing nasal stenosis would have to be located in the anterior-inferior portion of the nasal chambers to insure benefit from maxillary suture opening.

In 1970 Wertz made observations on sixty cases of palate splitting that he had done in his practice. He felt that expansion should be continued until overcorrection was attained to the extent that the lingual cusps of the maxillary teeth were riding up the buccal cusps of the mandibular teeth.

He found that there was a downward movement of the palate, with forward movement only happening in isolated cases. He also did palate expansion on dried skulls and found that the maxillonasal, maxillofrontal, and maxilloethmodial sutures were all disturbed, but the pterygopalatine and maxillopala -

tine sutures remained intact. If it were not for the resistance of the zygomatic arch to opening, a parallel opening of the suture would occur and the frontal process of the maxilla would move into the orbital cavity.

He demonstrated that there was increased gain in dental arch width contributed to by alveolar bending and associated tipping of the buccal teeth. It was for this reason that overcorrection was necessary, to make an allowance for the uprighting of the flared posterior teeth.

He found that the maxillary incisors consistantly uprighted and/or dropped posteriorly during the period of stabilization, and this helped to describe the mechanism by which gained arch length was dissipated. Widening of the circumoral group of muscles created more pressure on the labial surface of the maxillary incisors, which not only aided in closure of the incisor gap but also displaced the incisors lingually. Previously, only the pull of the interseptal fibrous connections was advanced as the reason for the rapid return of spaced incisors toward their original positions.

Wertz saw that with the dried skulls there was no resistance to the actual opening of the midpalatal suture, but the rigidty of the other maxillary articulations prevented maximum repositioning of the maxillary halves. Reduction of the activation schedule in adults would probably allow more

time for cellular adjustment at the suture, but it would also allow unfavorable bending of the alveolar process, tooth movement, and extrusion. Thus there would be more dental expansion than real skeletal repositioning.

Also Wertz observed that this procedure should only be applied for bilateral maxillary narrowness. If it was truly a unilateral constriction, bilateral expansion would cause the mandible to deviate to the non narrowed or normal side. This could cause a permanently displaced mandibular position and joint disturbances.

In 1969 Davis and Kronman did a study on expansion and showed that there was a forward position of point "A" and an increase in the angle formed by SN and the mandibular plane. The increase had a resulting tendency to open the bite. This was the result of the laterally moving maxillary posterior teeth occluding at a higher level on the cuspal inclines of the mandibular teeth. In comparing the configuration of the palatal vault before and after treatment, the height of the vault was found to be relatively constant, but it was more flattened.

With regard to the design of the palate-expansion appliance, there is some controversy. Christie (1967), Goldberg (1967), Haas (1970), and others believe in using a tissue-borne fixed split acrylic type. Maxillary six year molars and

deciduous maxillary first molars or maxillary first bicuspids are banded and buccal and lingual bars are placed as close to the gingiva as possible and contoured for maximum contact with the abutment bands and unbanded second deciduous molars or bicuspids to attain maximum anchorage. The resistance units are the inclined walls of the palatal vault, the buccal alveolar process, the posterior teeth, and the periodontal fibers. The acrylic does not touch any teeth; and the edges of all tissue-bearing surfaces are round off to avoid impingement on the tissues that possess a rich blood supply, namely, the rugae, the gingival tissue, and the tissue overlying the posterior alveolar foramina.

Rinderer (1966), Wertz (1970), and others modify this appliance by not placing buccal bars. They feel these bars bear no stress and only increase the difficulty of seating the appliance in place.

There is an all-wire framework appliance which Melson (1972), and others use which is relatively efficient in a mixed-dentition case or in a young full-dentition case. The only units of resistance here are the buccal teeth, the periodontal fibers, and the thin buccal alveolar plate. But according to Haas (1970), the all-wire framework appliance is unquestionably inferior to the base-borne appliance in older patients because of the resistance these patients may exhibit

to palatal suture opening.

Gray (1975), Timms (1968 and 1974), and others believe in using devices consisting of individual silver castings for the posterior three or four teeth which are cemented in place and connected by a stainless steel expansion screw. They feel that orthodontic bands alone reduce the rigidity of the appliance and permit too much tilting and probably insufficient nasal widening.

Frequently, according to Haas (1970), after the age of eighteen years, it is not possible to open the midpalatal suture. This may be due to the bridging of bone spicules across the suture or to the increased rigidity of the contiguous bones, especially the zygomaticofrontal buttress. In any event, the failure of the suture to open could result in extreme dental pain and even to teeth perforating the buccal alveolar plate if entirely tooth-supported anchorage is utilized. A surgical procedure has been proposed by Gorback and Infante (1975), which can be used to split the median palatal suture in adult orthodontic patients who have either bilateral posterior crossbites, or maxillary insufficiencies. The suture is split only on the palatal side of the maxilla. Two weeks are allowed for healing and then a conventional appliance is inserted. They find that this combined orthodontic and surgical procedure allows for an easy and rapid splitting of the palate in an adult

similar to that of a child.

Pritchard et al. (1956) and Enlow (1975) described the fundamental structure of sutures. They found that the sutures throughout their development exhibited five distinct layers of cells and fibers between the edges of the adjoining bones. These layers, in passing from edge of one bone to the edge of the other, were the first cambial layer, the first fibrous capsule, the loose cellular middle zone, the second fibrous capsule, and the second cambial layer. These were referred to as the intervening layers as opposed to two fibrous uniting layers which bound the suture externally and internally.

As the sutures matured, their cambial layers were gradually reduced to a single layer of flattened osteoblasts, the capsular layers thickened but their predominant fiber direction continued to be parallel to the sutural faces of the bones, while the middle layers became increasingly vascular. The uniting layers formed the strongest bond of union between the bones.

In explaining the growth of the nasomaxillary complex, Moyers (1966) described the human palate as containing three paired bones: the palatal process of the premaxilla, the palatal process of the maxilla, and the horizontal process of the palatine bone. During the first year of life, the palate and the maxilla increase in width and over-all dimensions by

external surface apposition, just as they do prenatally. This is termed generalized growth. Then growth becomes selective or localized to specific areas. The two transverse sutures of the palate are not really transverse but convex, the two convex surfaces facing each other as the lateral ends of the palatal processes of the maxilla send their horns out to envelop the premaxillary and palatine horizontal processes. Thus these sutures by their direction, contribute to lateral growth. The premaxillomaxillary suture closes in early infancy. After its closure, the anterior portion of the palate and maxilla become no wider, except for a small amount of apposition of labial alveolar bone to accommodate the larger roots of the permanent teeth. Most authorities state that the width of the palate increases posteriorly by sutural apposition in the midsagittal suture between the palatal processes of the maxilla. But Moyers feels that it is difficult to see how this can account for a great amount of lateral growth after the premaxillomaxillary suture fuses. By the time the first permanent molar is erupting, the palate has already reached its approximate maximal breadth. This is not later than the fifth year for, although the tooth may yet be in its crypt, the space needed for its complete development is already provided. Palatal width is thus achieved by growth at the sagittal suture, at the premaxillomaxillary suture and at the convex maxillopalatine

suture.

Baserga and Kisieleski (1963) explained the use of an autoradiographic label for the study of DNA synthesis, a refinement of the use of radioactive tracers. Tritium, radioactive hydrogen, has beta particles with a short range, traveling only about one micron. When the crystals of silver bromide embedded in a gelatin of the emulsion are struck by these particles, they are ionized with the result that the chemical action of a developer can then reduce the bromide to silver atoms. After the film is developed and fixed, each little aggregate of reduced silver atoms becomes a black dot visible under a microscope, and the black dots make up a picture of the radiation to which the film was exposed. A stain is then applied that penetrates the emulsion to show the outlines of the cells and their structures, (Kopriwa and Leblond, 1962).

Every cell capable of division goes through a production cycle. After division, mitosis, the cell enters a phase called G_1, during which it synthesizes RNA and proteins but no DNA. Sometime later it starts another phase, called S, in which it synthesizes DNA, RNA, and, at a stepped-up rate, protein. At the end of the S phase, the cell stops making DNA, reduces its production of proteins and goes into a relatively short phase called G_2, which prepares it for new

mitosis. During mitosis it produces no DNA, very little protein and sometimes no RNA, (Harbers et al.,1968).

Taylor et al. (1957) labeled DNA with tritiated thymidine, the precursor of thymidylic acid, which is one of the four building blocks of DNA, manufactured only in the nucleus of cells. Because thymidine is used by cells solely for the synthesis of DNA, the presence of this marker unmistakably identifies the nucleic acid. Therefore, an experimenter who takes a sample of cells from an animal shortly after thymidine has been injected into its tissues can be sure that the marker represents DNA and that the cells containing it were synthesizing DNA at the time the thymidine was injected. The percentage of cells bearing the label tells what proportion of cells are synthesizing DNA at a given time; hence this index, called the thymidine index, is a measure of the rate of cell division, or of how fast the cell population under investigation is proliferating.

With regards to histological findings, Kawata et al. (1970) studied the midpalatal sutures of rats after rapid expansion, observing the tissue reaction by means of microradiography. They used soft x-ray radiographs to evaluate the biological changes after appliances with U-shaped loops were cemented on the maxillary incisors of these animals for intervals of twenty-four hours to seven days. They

found that the animals subjected to twenty-four hours expansion showed a large midline boney defect. After forty-eight hours and four days the large radioluscent area in the midline showed mineralized spicules projecting into the defect. And by the seventh day mineralization of new bone could be seen in the midline surface of the maxilla.

West (1964) worked with five rhesus monkeys. He found that initially when heavy forces were directed against their maxillary posterior teeth via an acrylic expansion appliance, each maxilla rotated around a fulcrum in the zygomaticomaxillary suture without displacement of other bones. As forces continued to be applied the fulcrum shifted to the frontomaxillary suture, and maxillary displacement continued in a hinge-like movement. The zygomatic bones were displaced at right angles to the zygomaticomaxillary sutures during the latter movement of the maxillae. At the same time the palatine bones were moved apart slightly.

Also studying rhesus monkeys, Cleall et al. (1965) sacrificed an experimental animal that had been subjected to rapid expansion two weeks after the initial appliance activation, during which time four millimeters of expansion were achieved. They found that the expansion procedure did cause a disruption of the midpalatal suture, and that

this occurred very soon after the application of pressure. Histological sections stained with hematoxylin and eosin showed the suture to be dislocated leaving a boney defect filled with disorganized fibrous connective tissue and irregularly-positioned spicules of bone. The fibrous connective tissue was well vascularized and showed a mild chronic inflammatory response. While evidence of tissue damage to the suture was obvious, the cellular reaction noted after two weeks of expansion was both osteoblastic as well as osteoclastic.

Cleall brought up two points with regard to using the rhesus monkey as an experimental animal. First, dentally, these animals have a normal buccal segment relationship; and therefore, the expansion of the maxilla tends to move the teeth into an abnormal buccal crossbite arrangement. Also, while the rhesus monkey provides a close approximation to human morphology, differences do exist. For example, the monkey has a distinct and separate premaxilla which articulates with the maxillary bones. There is no continuous midline suture running through the premaxilla. The midpalatal suture joins the two premaxillary-maxillary sutures immediately posterior to the premaxilla, the configuration of the suture outline forming a Y.

In 1971 Murray and Cleall studied the early tissue

responses due to rapid expansion in these animals using tritiated proline. They found that the actual opening of the midpalatal suture took place between the fourth and seventh day of expansion. The mechanism of opening involved a series of distinct stages: an adaptation of the sutural connective tissue to the heavy forces; proliferation of the connective tissue and heavy resorption to permit physical separation of the boney processes; and heavy bone deposition in an attempt to maintain the sutural morphology. The premaxillary-maxillary and maxillopalatine sutures appeared to act as adjustment sites by allowing different degrees of opening in the interpremaxillary, intermaxillary and interpalatine sutures.

In 1972 Linge studied the tissue reaction in twenty-two rhesus monkeys to expansion appliances using hematoxylin-eosin staining and lead acetate to determine directions of bone growth. He found that mechanical tissue reactions characterized by displacement and distortion of tissue components, i.e. displacement of teeth within the alveolar socket, general widening of the intermaxillary suture, and deformation of bone, following a standardized expansion procedure varied in a differential manner. Sharpey's fibers under tension did not in themselves induce increased bone deposition at the site of fiber insertion. And the

direction of collagen fiber bundles in sutural interdigitation was secondary to the direction of bone growth.

Finally, Melsen (1972) actually used human tissue to study histological changes in the midpalatal suture after rapid expansion. Specimens for the histological analysis of the healing process three to six weeks after expansion were obtained by biopsies performed with a cylindrical trephine bur on children eight to thirteen years old. Sections were stained with hematoxylin-eosin and microradiographs were also made. He found that osteoblastic activity was primarily along the bone surfaces, sometimes, however, also along the bundles of fibers which crossed the suture and could be followed into the bone. In the older children, there were numerous resorption zones on the bone surfaces and active ossification around bone processes and bone islands. This seemed to be attributed to the strong interdigitation of the bone processes, which prevents the two halves of the suture from separating without minor fractures in the suture line. The location of resorption zones opposite bone islands can also be explained in this manner, as osteoclastic activity is seen as the first stage in remodelling and repair after a fracture. The more marked the interdigitation of the suture, the greater the area of fracture is to be found after expansion.

MATERIALS AND METHODS

The animals selected for this study were six rhesus monkeys purchased from Primate Imports, Port Washington, New York. Four females and two males were used, with dentitions equivalent to approximately nine to twelve year old children. Four monkeys selected at random, served as experimental animals and two as controls. Both of the controls were females. Two of the experimental animals and one control had their deciduous maxillary first molars present; and in the remaining monkeys, the maxillary first premolars had erupted. At the start of the experiment, the weight range for the monkeys was 2,300 gms. to 5,800 gms., with the average weight being 4,150 gms.

The animals were housed in individual squeeze cages at the Animal Research Facilities of Loyola University Medical Center. They were fed a standard diet of Purina Monkey Chow and given unrestricted amounts of water. Due to the stress from transportation and other environmental changes, an initial two week isolation period was needed until the animals became adjusted to their new quarters and in order to condition and treat them with antibiotics if necessary. Fortunately, throughout the experiment all

the animals remained in good health. No difference was observed between the experimental and control animals as to feeding habits, weight gain, or general behavior.

All operations were accomplished under general anesthesia. The monkeys were anesthetized during the more lengthy initial procedures with Sernylan (phencyclidine hydrochloride, 3 mg. per kilogram body weight), injected intramuscularly. Atrosol (atropine sulfate, 1 ml. per twenty pounds body weight) was also administered subcutaneously to help prevent obstruction of the airway by oral secretions. To accomplish the injections, the monkey was forced against the sliding door of the squeeze cage and his legs were rendered immobile. To handle the animals, double leather gloves were worn to protect the handler from bites and scratches.

Monkeys may have chronic, subclinical infections with any number of potentially pathogenic organisms. Many infections in monkeys are communicable both to other monkeys and to man, and are potentially fatal to the sick animal. Aseptic operative procedures, therefore, were practiced utilizing sterile surgical gloves, face masks, gowns and instruments. The monkeys were individually transferred from their cages to the animal operating room where all experimental procedures were performed.

Preliminary impressions of both arches were taken on each animal, using softened baseplate wax. Plaster models were then poured from these wax impressions, and custom acrylic trays were fabricated on these models.

Complete initial records were then taken of each monkey. These included the animal's weight, length, collar size, an occlusal x-ray, wax bite, and rubber base upper and lower impressions using the custom trays.

Stainless steel orthodontic bands were then adapted to the permanent maxillary first molars and deciduous maxillary first molars or maxillary first premolars of the four experimental animals, after these teeth had been prepared by slicing interproximally with Lightning Strips. Green compound impressions were taken using the custom trays. The bands were removed from the mouth, oriented in the impressions, and casts were poured in orthodontic stone.

With these casts as working models, four palate splitting appliances were fabricated. 0.036 inch stainless steel wires were adapted to the lingual surfaces of the bands and to the intervening teeth, and the free ends were bent toward the midline. These wires were then soldered to the bands so that the free ends were about one millimeter away from the palatal surface. Labial

0.036 inch stainless steel bars were also soldered to the bands for added support. The casts were painted with separating medium and four millimeter OIS expansion screws that opened 0.8 mm. with each 360 degree turn were then positioned in the center of the palates in such a manner that the appliances opened when the wrenches were moved from front to back. Fast-cure acrylic was added to cover the screw mechanisms.

When the acrylic had completely set, the appliances were removed from the casts, trimmed away from the teeth and bevelled anteriorly and posteriorly. The screws were given several turns to test their action. All acrylic surfaces that were to contact tissue were smoothly rounded and polished. The screws were returned to their position of maximum closure and the bands were checked for cleanliness (Figure 1).

Before the appliances were cemented in place, individualized flexible plastic collars were fitted to the necks of both the control and experimental animals. Wire guidelines were positioned in the four corners of each cage to stabilize the collars. With these shields in place, the monkeys were unable to reach their mouths with their hands. This would tend to eliminate the possibility for them to dislodge the appliance manually. Once the collars were

placed, all the animals were hand-fed twice a day until the end of the experiment. Their diet consisted of a mush of ground Purina Monkey Chow pellets, fresh bananas, and a vitamin and mineral supplement (Squibb's Vionate). Plastic water bottles were fixed to each cage which the animals could reach freely. All the monkeys were given a one week period to adapt to their collars and to insure that their weight remained stable.

Then the appliances were cemented in the four experimental animals using Caulk's Grip cement. The abutment teeth were isolated with cotton rolls, dried and lightly serrated on the buccal and lingual with a 701 tapered fissure bur. After the cement had completely hardened, the excess was removed with hand instruments and the screws were activated two initial quarter turns. For the next eight days, each appliance was activated two quarter turns daily. During these procedures, the animals were anesthetized with Ketaset (ketamine hydrochloride, 5-10 mgs. per lb. body weight) intramuscularly, a much shorter acting drug than Sernylan. Atrosol was continued to be administered subcutaneously. The control animals were anesthetized each day also so that all the monkeys were handled the same amount during the experimental period.

On the tenth day each animal received a single intravenous injection of tritiated thymidine (0.7 μc/gm. body weight, specific activity of 1.9 c/mM at a concentration of 1 mc/ml). New occlusal x-rays and rubber base impressions were taken. Three hours later each animal was sacrificed by injecting Beuthanasia Regular (sodium pentobarbital, 1 ml. per 5 lbs. body weight) intracardially. The monkeys were then decapitated, their mandibles were removed, and all tissues were stripped off the skulls. Each animal's maxillary complex was dissected out and placed in an individually labelled container filled with 10% buffered Formalin for seven days.

One cm^2 blocks of the midpalatal suture, one from the anterior portion of the hard palate and one from the posterior portion of the hard palate, were dissected from each skull. Also one cm^2 blocks of the maxillary-palatal suture, one from the right side and one from the left side, were removed. Finally, blocks of the maxilla containing the first permanent molars and first deciduous molars or first premolars were dissected out from the skulls. All tissues were again fixed in 10% Formalin.

All specimens were decalcified from two to four weeks. Coronal sections of the midpalatal sutures and periodontal ligaments of the teeth were cut from these

blocks. Sagittal sections were cut from the blocks containing the maxillary-palatal sutures. Ten sections from each block were used for hematoxylin and eosin staining. And twenty sections from each block were used to obtain radioautograms using Kodak NTB3 liquid emulsion. The sections, six micrometers in thickness, were first exposed for four weeks in a lighttight box at $4^{o}C$ and later developed, washed, fixed, and stained with nuclear fast red indigo carmine according to the technique of Kopriwa and Leblond (1962).

All tissues were studied using a reticle with an area of $(110\mu m)^2$ at 450 magnification. The cell density was defined as the mean number of cells per $(110\mu m)^2$. The labeling index was defined as the mean number of labelled cells per one thousand cells counted. Cells with three or more granules were judged as positive. Osteoblasts, osteoclasts, fibroblasts, and undifferentiated mesenchymal cells were counted. Osteocytes and endothelial cells were not counted.

For the purpose of having a standardized and typical morphology in the sutural areas to be evaluated, two or three units of sutural interdigitation from the center of each section were studied. As defined by Linge (1972), each of these consisted of one boney eminence, the corre-

sponding concavity of the opposing bone, and the intervening sutural tissue. One thousand cells in each of five randomly selected sections of each of the sutures from every animal were counted, and the mean cellular density and labeling index were determined for each suture.

In studying the periodontal ligaments of the right and left maxillary molars and maxillary first premolars or maxillary first deciduous molars of each animal, again for the sake of standardized and typical morphology, the lingual surface of the palatal root was used. The reticle was aligned along the cementum at a level perpendicular to the crest of the alveolar bone and moved apically for the cell count. One thousand cells were counted in each of two randomly selected sections from each tooth from every animal, and the cell density and labeling index were again determined.

The means and standard deviations of the labeling indexes and cell densities were calculated. These means were compared by using the Student's t test to see if there was a significant difference between the controls and treated animals at the 5% level.

The beginning and ending maxillary casts were evaluated as to changes in interdental dimensions. Using

a fine-pointed caliper, the distances between the cusp tips of the deciduous cuspids and the distances between the bases of the mesial fossae of the maxillary first permanent molars were measured on each cast.

RESULTS

After ten days of intramaxillary forces, all the treated animals exhibited complete bilateral crossbites. Contrary to what is commonly observed in humans treated with palate splitting appliances, no gaps were observed between the central incisors of any of the monkeys. This could be explained by the fact that the monkey has a distinct and separate premaxilla which articulates with the maxillary bones, and there is no continuous midline suture running through the premaxilla as pointed out by Cleall et al. (1965).

The occlusal radiographs showed the incisive foramen to be quite large in all the animals. In the controls, the midpalatal suture appeared narrow and well defined, starting just posterior to the foramen. In all the treated animals at the end of the experiment, the suture was shown to have opened two to three millimeters, and the opening was fairly parallel from anterior to posterior (Figure 2).

Some of the common elements found in all the sutures studied were fibroblasts, undifferentiated mesenchymal cells and other cells of loose connective tissue, osteo-

blasts, osteoclasts, collagenous fibers, intercellular vacuoles, blood vessels, and endothelial cells. In the sutures of the control animals adjacent to each bony surface was a zone containing heavy bundles of collagenous fibers and relatively few cells. Separating these outer layers was a central zone which was very rich in cells. These cells were clustered in a random fashion. The strong collagenous fibers were arranged in parallel bundles that appeared to course diagonally from one bony surface to the other. Their course was interrupted in the central zone where the thin fibers formed a meshwork about the numerous cells. Blood vessels of varying diameter were seen in all three zones. Osteoblasts and osteoclasts, where present, were found between the fiber bundles on the bony surfaces. No capsular layer separating the intermediate from the cambial layers was observed (Figure 3, 5 and 9).

The intermaxillary sutures in the control animals were thin, well-organized bands of fibrous connective tissue running between finger-like projections, bony processes that were well interdigitated. These processes had their long axis oriented in a horizontal direction which would coincide with the direction of the experimental influence of the palate splitting appliance (Figure 3). The posterior areas of the intermaxillary

suture appeared to have less bony interdigitations. The maxillopalatine sutures were slightly narrower than the intermaxillary sutures and were slightly less complex in their morphological configuration (Figure 5).

After expansion, the intercellular spaces and blood vessels within the sutures had increased dimensions. The sutural bony projections were tipped and withdrawn from their depressions. Irregularly-positioned spicules of bone were noted in some of the sutures. These were portions of bony processes that were fractured off as the sutures were opened. The bony defects were filled with disorganized fibrous connective tissue. All fiber bundles appeared to be stretched in the direction of the mechanical pull (Figures 4 and 6). Of the areas studied, the increase in sutural width seemed to be the greatest in the posterior portions of the intermaxillary suture. There was no consistent pattern in any of the sutures studied as to the position of the labeled cells (Figure 7 and 8).

Examination of the periodontal structures indicated that some buccal tipping of teeth had occurred. The periodontal ligaments of the deciduous first molars, the premolars, and the molars were compressed on their cervical buccal aspects and stretched on their cervical

palatal aspects (Figure 11, 13 and 14). The maxillary first molars, since they were larger teeth with more root surface area, resisted the tipping forces much more than either the first maxillary premolars or the first deciduous maxillary molars. All abutment teeth showed a significant increase in DNA synthesis in their periodontal ligaments. Again there was no consistent pattern to the arrangement of the labeled cells, as they were found at all levels of the ligaments (Figure 12).

When the appliances were removed, moderate tissue irritation was noted on the palatal mucosa of one of the treated animals. This could be attributed either to faulty appliance fabrication or insertion.

In studying the maxillary plaster casts, the interdental width from the cusp tip of one deciduous cuspid to the cusp tip of the opposite deciduous cuspid was seen to increase 2.57mm. $\pm$ 0.25 in the treated animals. The intermolar width from the mesial fossa of one first permanent molar to the mesial fossa of the opposite first permanent molar was seen to increase 2.85mm. $\pm$ 0.69 in the treated animals (Table 1). Both of these measurements were less than the 3.6mm. of expansion calculated directly from the screw mechanism.

The histological results showed that there was an increase in the labeling index of the intermaxillary suture in the anterior region from 0.50 ± 0.14 cells per thousand cells in the controls to 40.47 ± 27.47 cells per thousand cells in the experimental animals. And in the posterior region, there was an increase in the labeling index from 0.50 ± 0.04 cells per thousand cells in the controls to 33.05 ± 27.99 cells per thousand cells in the treated animals. These increases were not significant at the 5% level (Table 2).

The cell density, however, decreased in the anterior region of the intermaxillary suture from 142.85 ± 9.12 cells/$(110\mu m)^2$ in the controls to 76.45 ± 7.40 cells/$(110\mu m)^2$ in the experimental animals. And in the posterior region there was also a decrease from 142.80 ± 27.44 cells/$(110\mu m)^2$ in the controls to 75.17 ± 7.07 cells/$(110\mu m)^2$ in the treated animals. Both of these decreases were significant at the 1% level (Table 3).

In examining the maxillopalatine suture, the right side showed an increase in the labeling index from 0.55 ± 0.49 cells per thousand cells in the controls to 30.52 ± 16.17 cells per thousand cells in the treated animals. This increase was significant at the 5% level. The left side also showed an increase from 0.65 ± 0.07

cells per thousand cells in the controls to 30.69 ± 28.57 cells per thousand cells in the treated animals. This increase was not significant at the 5% level (Table 4).

The cell density again decreased in the maxillo-palatine suture on the right side from 106.49 ± 2.40 cells/$(110\mu m)^2$ in the controls to 42.97 ± 1.30 cells/$(110\mu m)^2$ in the treated animals. And on the left side, the decrease was from 95.19 ± 8.34 cells/$(110\mu m)^2$ in the controls to 53.29 ± 3.54 cells/$(110\mu m)^2$ in the experimental animals. Both of these decreases were significant at the 1% level (Table 5).

The results of studying the periodontal ligaments of the maxillary first premolars or maxillary deciduous first molars on their tension side showed an increase in the labeling index on the right side from 0.40 ± 0.14 cells per thousand cells in the controls to 12.47 ± 6.37 cells per thousand cells in the treated animals. There was also an increase on the left side from 0.40 ± 0.28 cells per thousand cells in the controls to 13.17 ± 4.54 cells per thousand cells in the experimental animals. These teeth served as the anterior abutments for the palate splitting appliances in the treated animals. Both increases were significant at the 5% level (Table 6).

The cell density, however, decreased for the periodontal ligaments of the premolars or deciduous first molars on the right side from 96.74 ± 6.43 cells/$(110\mu m)^2$ in the controls to 60.72 ± 13.22 cells/$(110\mu m)^2$ in the treated animals. This decrease was significant at the 5% level. And on the left side, the decrease was from 108.64 ± 13.50 cells/$(110\mu m)^2$ in the controls to 57.64 ± 7.40 cells/$(110\mu m)^2$ in the experimental animals. This decrease was significant at the 1% level (Table 7).

From studying the periodontal ligaments of the maxillary first molars on their tension side, the results showed an increase in the labeling index from 3.50 ± 2.96 cells per thousand cells in the controls to 16.79 ± 4.75 cells per thousand cells in the experimental animals on the right side. And on the left side, there was an increase in the labeling index from 4.30 ± 4.38 cells per thousand cells in the controls to 16.44 ± 3.70 cells per thousand cells in the treated animals. These teeth served as the posterior abutments for the palate splitting appliances in the experimental animals. Both increases were significant at the 5% level (Table 8).

The cell density of the periodontal ligaments of the molars showed only a slight decrease on the right side from 70.44 ± 1.90 cells/$(110\mu m)^2$ in the controls to

70.17 $\pm$ 7.53 cells/$(110\mu m)^2$ in the treated animals. And on the left side there was also only a slight decrease from 77.09 $\pm$ 5.23 cells/$(110\mu m)^2$ in the controls to 69.22 $\pm$ 9.08 cells/$(110\mu m)^2$ in the experimental animals. Both of these decreases were not significant at the 5% level (Table 9).

DISCUSSION

The changes observed in the intermaxillary and maxillopalatine sutures after ten days of palate splitting therapy appear to follow a set pattern. As the adjacent bones are separated through this procedure, the relative cellularity in these sutures is seen to decrease. Since the tissues are being stretched apart, fewer cells per given area are found in these sutures of the experimental animals than in the controls. This would seem to account for the decreased cell density observed in these areas. At the same time, this procedure serves as a stimulus for the increase of DNA synthesis and thus mitosis in these areas, as indicated by the increased labeling indexes in the experimental animals.

A possible explanation of the stimulus for the increase of DNA synthesis in these sutures is the loss of contact inhibition between cells as these tissues are being distended by the forces of the palatal appliances. Abercrombie (1967) explains that this interesting phenomenon of contact inhibition is actually the inhibition of cell mobility and also of mitotic

activity that is observed when cultured cells come in contact. This is frequently observed in cultures growing on a solid support such as a glass surface or a millipore. As long as cells float freely in the nutrient medium they generally divide every twenty-four hours. However, when they come in close contact in a monolayer, the rate of mitosis slows down and there is inhibition of cell division. DeRobertis et al. (1970) report that this contact inhibition depends on some unknown signal between cells in contact and not on a diffusible substance acting at a distance.

Thus conceivably in this study, the cells in the intermaxillary and maxillopalatine sutural tissues of the experimental animals would have their contacts reduced and are released to enter into mitosis. Also the blood vessels and intercellular spaces are shown to have increased dimensions in these sutures. There would be an increase in the vascular permeability in these areas too, and a loss of the gel state of the intercellualr ground substance. This would produce both physical space and an increase in the amount of available nutrients that are required for growth.

Although these trends toward increased DNA synthesis are obvious from the data collected, a statistically

significant difference is still not found between the labeling indexes of the experimental and control groups in Table 2 and Table 4 on the left side at the 5% level using the Student's t test. This can be explained by the fact that the sample size is small. The differences between the means of the experimental and control groups are quite large in all areas counted. If the degrees of freedom were slightly higher, that is, if more animals would have been used in this study, there would, more than likely, have been a definite significant statistical difference in all instances.

With regards to the fundamental structure found in all the sutures studied, only three layers are observed. There are cambial layers rich in collagenous fibers adjacent to bony surfaces, and these cambial layers are separated by an intermediate zone rich in cells. These three layers are consistent with Linge (1972). No capsular layers as shown by Pritchard et al. (1956) are observed.

The histological observations of the intermaxillary and maxillopalatine sutures in the experimental animals after expansion are similar to what Cleall et al. (1965), Starnbach et al. (1966), and Murray and Cleall (1971) have reported. All collagenous fiber bundles are

stretched in the direction of the mechanical pull of the appliance. Osteoblastic activity is noted along the sutural bony margins with osteoid tissue been laid down (Figure 6 and Figure 10).

There is an increase in the labeling indexes of the periodontal ligament on the palatal side of the abutment teeth in all of the experimental animals after palatal expansion. Again the loss of contact inhibition would seem to be a conceivable explanation for the increased mitotic activity in these areas since the periodontal membranes are found to be stretched on the palatal aspect. This stretching of the periodontal membrane is consistant with what Starnbach et al. (1966) have reported. As the periodontal fibers are pulled, the relative cellularity, and thus the cell density, in these ligaments is decreased after expansion except in the maxillary first molar. Since these teeth are larger than the other abutment teeth with more root surface area, they seem to have resisted the tipping forces much more than either the first maxillary premolar or the first deciduous maxillary molar.

The occlusal radiographs of all the experimental animals after ten days of palate splitting therapy show a parallel opening to the intermaxillary suture from anterior to posterior. This finding is inconsistent

with the findings of Wertz (1970). He states that the palatal void created by the separation of the maxillary halves almost always appears nonparallel, with the wider opening being at the anterior. His study involves sixty patients from his private practice. Thus a possible explanation for this discrepancy in findings could be the anatomical difference in the palate between the human and the rhesus monkey. As previously stated, the rhesus monkey has a separate and distinct premaxilla which articulates with the maxillary bones, and there is no continuous midline suture running through the premaxilla (Cleall et al., 1965).

It is felt that the moderate tissue irritation noted on the palatal mucosa of one of the treated animals after appliance removal could have been eliminated with a different impression technique. If an alginate material had been used instead of green compound for the impressions, there would have been a more accurate reproduction of the soft tissue on the working models on which the appliances were fabricated. Goldberg (1968) feels that these impressions should always be taken in alginate because compound will cause considerable impingement upon the soft tissue.

Palate splitting is by no means the complete treatment of any orthodontic case. But from the ease with which this procedure is accomplished in the experimental animals, it appears that this form of therapy could help to make a case that is ordinarily considered most difficult become a relatively routine problem for the orthodontist after suture opening.

SUMMARY AND CONCLUSIONS

Palate splitting procedures were performed on four young rhesus monkeys using conventional acrylic appliances with screw mechanisms that opened four millimeters. Two animals of the same age were used as controls in this study. Complete records were taken on each monkey at the beginning and end of the experiment, including occlusal radiographs and dental casts. The appliances were activated two quarter turns initially and two quarter turns daily for the next eight days. On the tenth day each animal received a single intravenous injection of tritiated thymidine and was sacrificed three hours later. The intermaxillary suture, the maxillopalatine sutures, and the periodontal ligaments of either the first maxillary premolars or the first maxillary deciduous molars and the first maxillary molars on each animal were evaluated histologically with regard to their labeling index and their cell density.

The following results were obtained:

1. The interdental expansion was less than that calculated directly from the screw mechanism, and the teeth appeared to be tipped slightly to the buccal.
2. The radiographic openings of the midpalatal sutures were

two to three millimeters wide and fairly parallel from anterior to posterior.

3. No gap was observed between the central incisors of any of the treated animals.
4. The intermaxillary and maxillopalatine sutures in the control animals were thin, well-organized bands of fibrous connective tissue running between finger-like projections, bony processes that were well interdigitated. In the experimental animals, these sutural bony projections were tipped and withdrawn from their corresponding depressions. The bony defects were filled with disorganized fibrous connective tissue.
5. The periodontal ligaments in the control animals were regular in width around each tooth with fiber bundles that were well oriented. The periodontal ligaments of the abutment teeth in the experimental animals were stretched on their cervical palatal aspects and compressed on the cervical buccal aspects suggesting that some buccal tipping of these teeth had occurred.
6. The cell density decreased in the intermaxillary suture, the maxillopalatine sutures, and the periodontal ligaments of the maxillary first premolars and first maxillary deciduous molars of the treated

animals but not in the periodontal ligaments of the maxillary first molars.

7. There was an increase in the labeling indexes of the intermaxillary suture, the maxillopalatine sutures, and periodontal ligaments of the maxillary first premolars, maxillary first deciduous molars, and maxillary first molars of all the treated animals.

On the basis of the preceding data, the general conclusion indicated by this investigation is that after ten days there is an alteration in the cellular proliferation and cell density in the palatal sutures and periodontal ligaments in the maxillary dentition of monkeys subjected to palate splitting therapy.

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TABLE 1

MEASUREMENTS OF PLASTER CASTS
(in mm)

	INTERCUSPID WIDTH		INTERMOLAR WIDTH	
	Begin	End	Begin	End
Control I	20.0	20.2	24.5	24.5
Control II	20.5	20.5	24.7	25.0
Treated I	25.1	27.4	29.1	31.1
Treated II	22.0	24.6	26.9	29.5
Treated III	20.0	22.9	24.1	27.6
Treated IV	25.0	27.5	28.0	31.3
Mean Increase After Expansion	2.57 $\pm$ .25		2.85 $\pm$ .69	

TABLE 2

LABELING INDEX OF THE INTERMAXILLARY SUTURE
(labeled cells/1000 cells)

	ANTERIOR	POSTERIOR
Control I	0.4	0.8
Control II	0.6	0.2
Mean	0.50 ± .14	0.50 ± .04
Treated I	9.2	11.1
Treated II	70.4	74.1
Treated III	55.1	22.9
Treated IV	27.2	24.1
Mean	40.47 ± 27.47	33.05 ± 27.99
P	>.05	>.05

TABLE 3

CELL DENSITY OF THE INTERMAXILLARY SUTURE
(cells/$(110\mu m)^2$)

	ANTERIOR	POSTERIOR
Control I	149.3	123.4
Control II	136.4	162.2
Mean	142.85 $\pm$ 9.12	142.80 $\pm$ 27.44
Treated I	86.4	81.2
Treated II	69.4	67.6
Treated III	72.5	81.2
Treated IV	76.9	70.7
Mean	76.45 $\pm$ 7.40	75.17 $\pm$ 7.07
P	$<.01$	$<.01$

TABLE 4

LABELING INDEX OF THE MAXILLOPALATINE SUTURE
(labeled cells/1000 cells)

	RIGHT	LEFT
Control I	0.9	0.6
Control II	0.2	0.7
Mean	0.55 ± .49	0.65 ± .07
Treated I	10.1	13.1
Treated II	48.9	73.3
Treated III	27.8	15.7
Treated IV	35.3	20.7
Mean	30.52 ± 16.17	30.69 ± 28.57
P	$<.05$	$>.05$

TABLE 5

CELL DENSITY OF THE MAXILLOPALATINE SUTURE
(cells/(110μm)^2)

	RIGHT	LEFT
Control I	108.2	101.1
Control II	104.8	89.3
Mean	106.49 ± 2.40	95.19 ± 8.34
Treated I	41.6	53.8
Treated II	44.7	49.1
Treated III	43.1	52.6
Treated IV	42.5	57.7
Mean	42.97 ± 1.30	53.24 ± 3.54
P	$<.01$	$<.01$

TABLE 6

LABELING INDEX OF THE PERIODONTAL LIGAMENT
OF THE MAXILLARY FIRST PREMOLAR
(labeled cells/1000 cells)

	RIGHT	LEFT
Control I*	0.5	0.6
Control II	0.3	0.2
Mean	0.40 ± .14	0.40 ± .28
Treated I*	4.7	7.6
Treated II	19.9	16.2
Treated III	10.9	17.5
Treated IV*	14.4	11.4
Mean	12.47 ± 6.37	13.17 ± 4.54
P	$<.05$	$<.05$

*Deciduous First Molar

TABLE 7

CELL DENSITY OF THE PERIODONTAL LIGAMENT
OF THE MAXILLARY FIRST PREMOLAR
(cells/(110μm)^2)

	RIGHT	LEFT
Control I*	92.2	99.1
Control II	101.3	118.2
Mean	96.74 ± 6.43	108.64 ± 13.50
Treated I*	42.1	47.3
Treated II	65.4	61.6
Treated III	73.1	64.1
Treated IV*	62.3	57.6
Mean	60.72 ± 13.22	57.64 ± 7.40
P	$<.05$	$<.01$

*Deciduous First Molar

TABLE 8

LABELING INDEX OF THE PERIODONTAL LIGAMENT
OF THE MAXILLARY FIRST MOLAR
(labeled cells/1000 cells)

	RIGHT	LEFT
Control I	5.6	7.4
Control II	1.4	1.2
Mean	3.50 $\pm$ 2.96	4.30 $\pm$ 4.38
Treated I	22.4	15.6
Treated II	16.5	21.9
Treated III	17.5	14.4
Treated IV	10.8	13.9
Mean	16.79 $\pm$ 4.75	16.44 $\pm$ 3.70
P	$<.05$	$<.05$

TABLE 9

CELL DENSITY OF THE PERIODONTAL LIGAMENT
OF THE MAXILLARY FIRST MOLAR
(cells/(110μm)^2)

	RIGHT	LEFT
Control I	71.8	80.8
Control II	69.1	73.4
Mean	70.44 ± 1.90	77.09 ± 5.23
Treated I	60.9	56.3
Treated II	72.7	77.6
Treated III	68.3	71.2
Treated IV	78.8	71.8
Mean	70.17 ± 7.53	69.22 ± 9.08
P	>.05	>.05

Figure 1 Palate splitting appliance with expansion screw on working model.

Figure 2 Occlusal radiographs of midpalatal region before (left) and after (right) expansion.

ILLUSTRATIONS

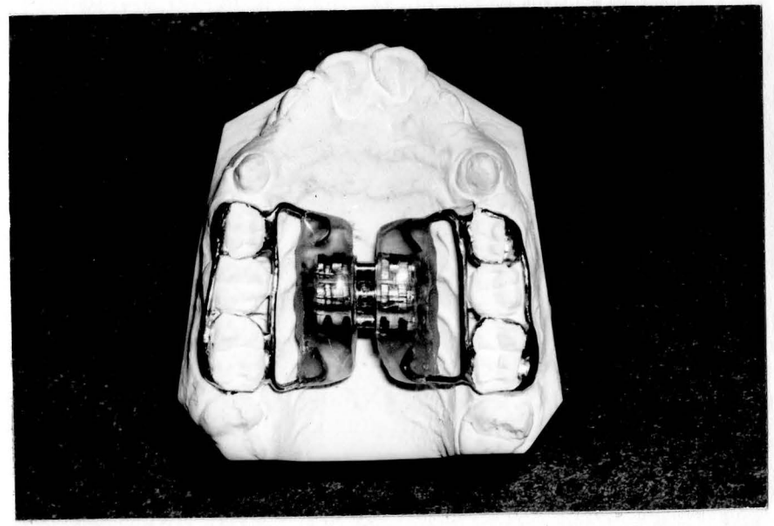

Figure 1

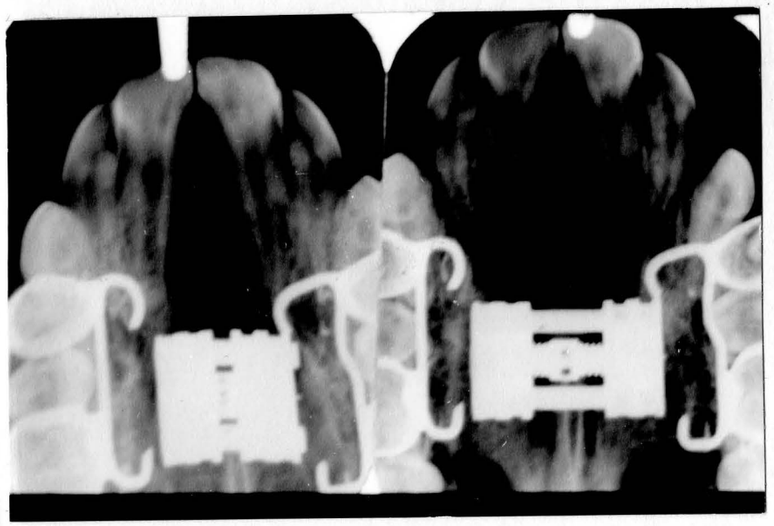

Figure 2

Figure 3 Photomicrograph (X40) of a coronal section through the anterior portion of intermaxillary suture of a control animal showing the uniformity of the fibrous band of suture material.

Figure 4 Photomicrograph (X40) of a coronal section through the anterior portion of the intermaxillary suture of an experimental animal showing the disrupted sutural connective tissue.

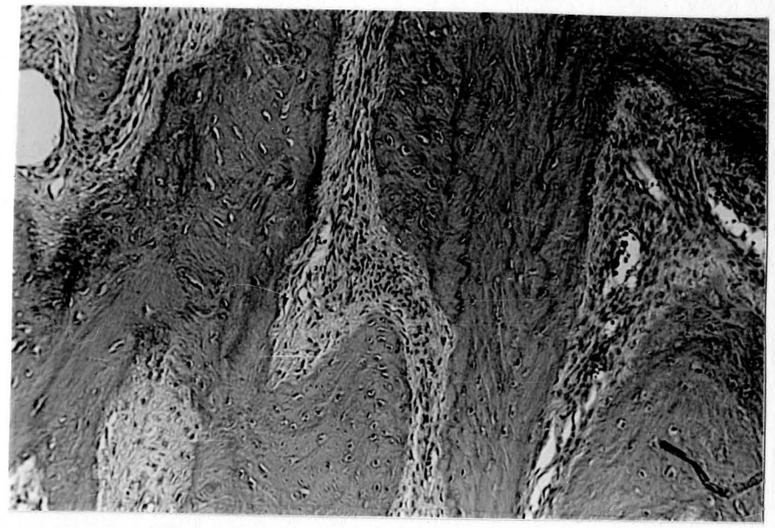

Figure 3

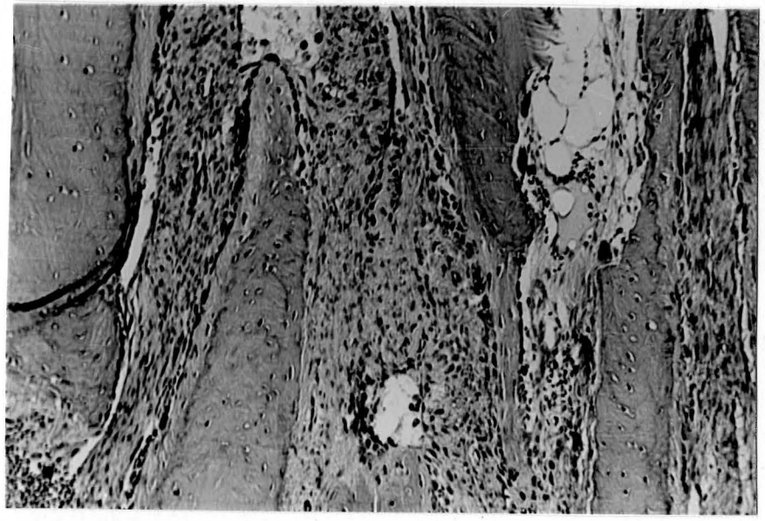

Figure 4

Figure 5 Photomicrograph (X40) of a coronal section through the posterior portion of the inter-maxillary suture of a control animal showing narrow, well-organized suture.

Figure 6 Photomicrograph (X40) of a coronal section through the posterior portion of the inter-maxillary suture of an experimental animal showing sutural material being stretched. Note the osteoid seam and the osteoblastic activity.

O - Osteoid tissue

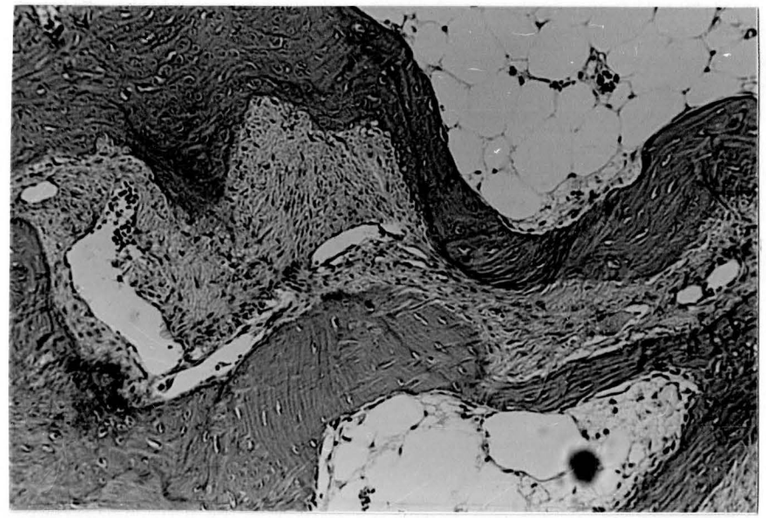

Figure 5

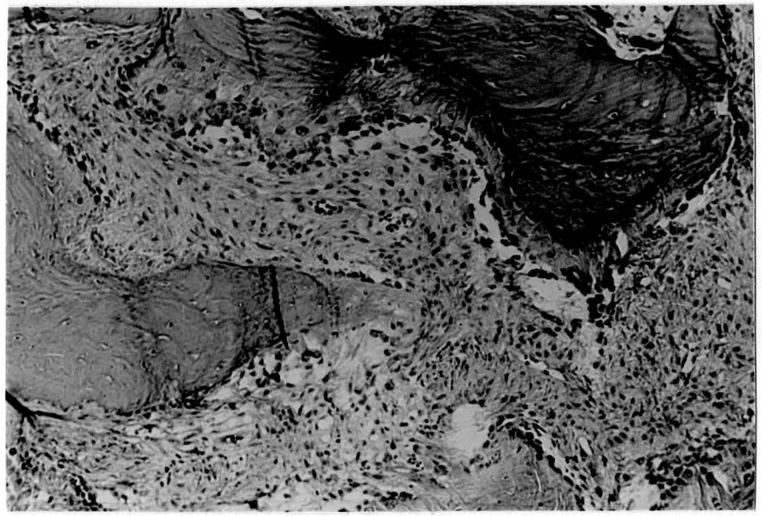

Figure 6

Figure 7 Photomicrograph (X100) of an autoradiogram showing labeled cells in anterior portion of intermaxillary suture of an experimental animal.

Figure 8 Photomicrograph (X100) of an autoradiogram showing labeled cells in posterior portion of the intermaxillary suture of an experimental animal.

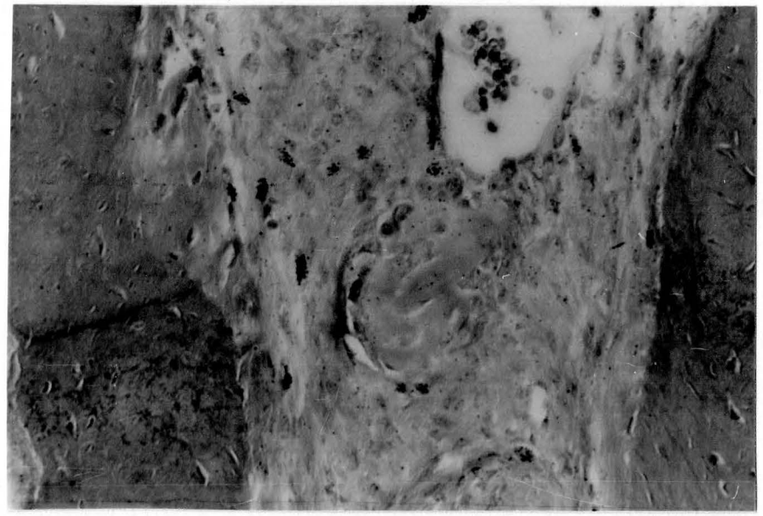

Figure 7

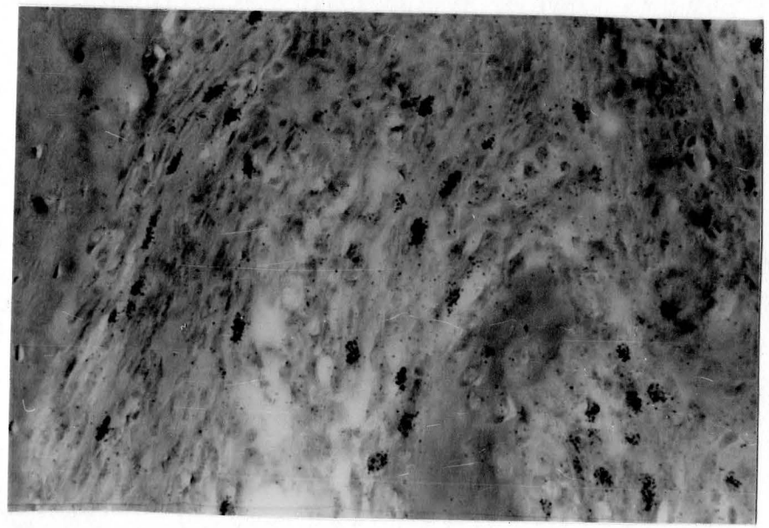

Figure 8

Figure 9 Photomicrograph (X100) of a sagittal section of the maxillopalatine suture in a control animal showing a unit of sutural interdigitation.

Figure 10 Photomicrograph (X100) of a sagittal section of the maxillopalatine suture in an experimental animal showing disorganized sutural fibrous connective tissue. Note the osteoid seam and osteoblastic activity.

O - Osteoid tissue

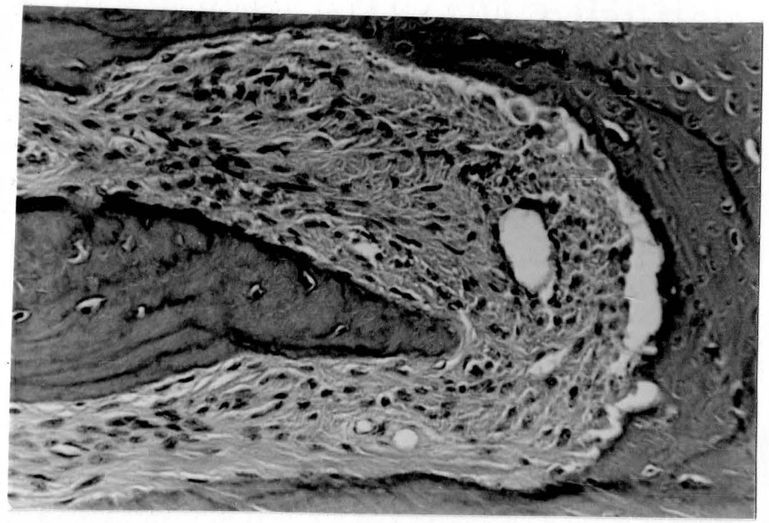

Figure 9

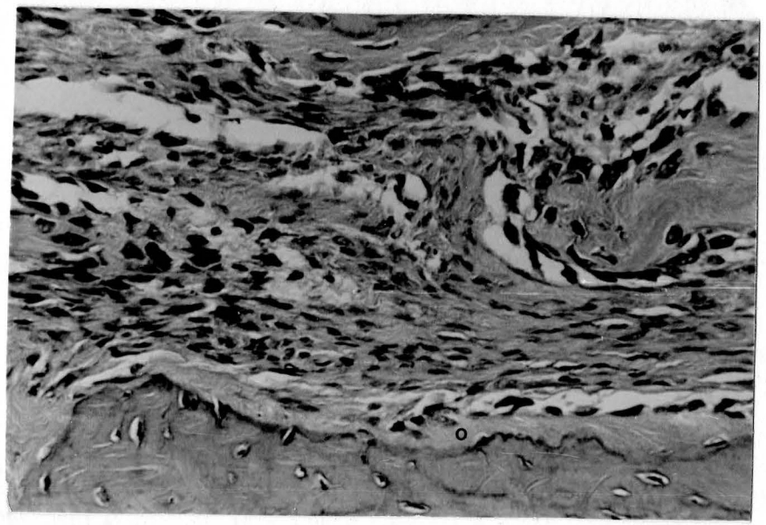

Figure 10

Figure 11 Photomicrograph (X100) of the periodontal ligament of the maxillary first premolar in an experimental animal showing osteoblastic activity.

C - Cementum

PL - Periodontal ligament

O - Osteoid tissue

Figure 12 Photomicrograph (X100) of autoradiogram showing labeled cells in the palatal portion of the periodontal ligament of the maxillary first premolar in an experimental animal.

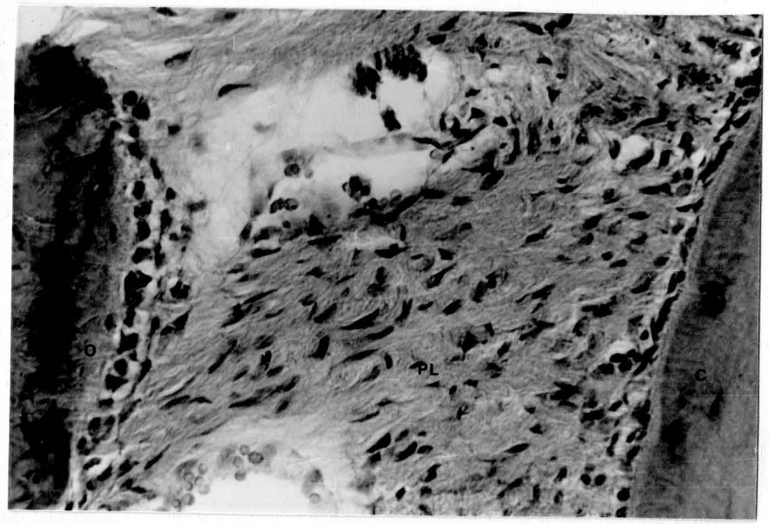

Figure 11

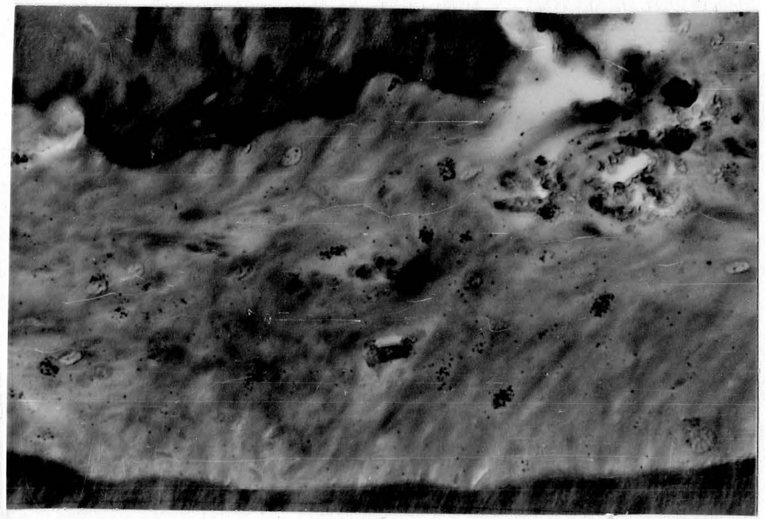

Figure 12

Figure 13 Photomicrograph (X100) showing osteoclastic activity in the buccal cervical area of the periodontal ligament of the maxillary first molar of an experimental animal.

C - Cementum

PL - Periodontal ligament

OC - Osteoclasts

Figure 14 Photomicrograph (X100) showing osteoblastic activity in the palatal cervical area of the periodontal ligament of the maxillary first molar of an experimental animal.

C - Cementum

PL - Periodontal ligament

B - Bone

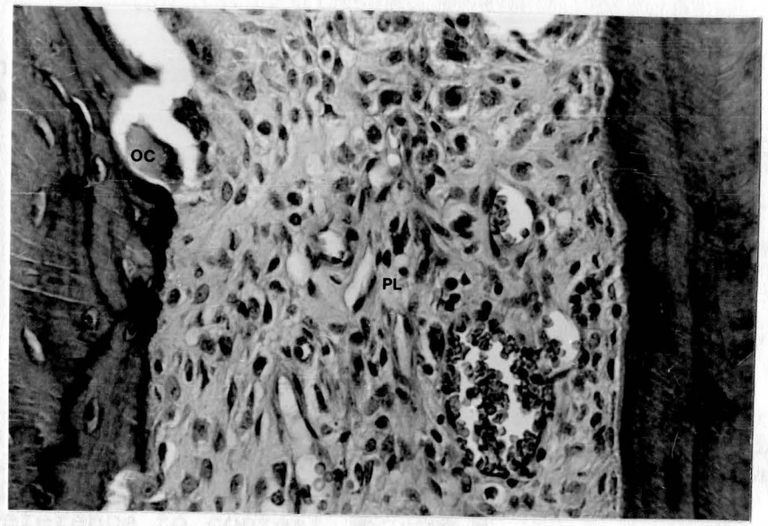

Figure 13

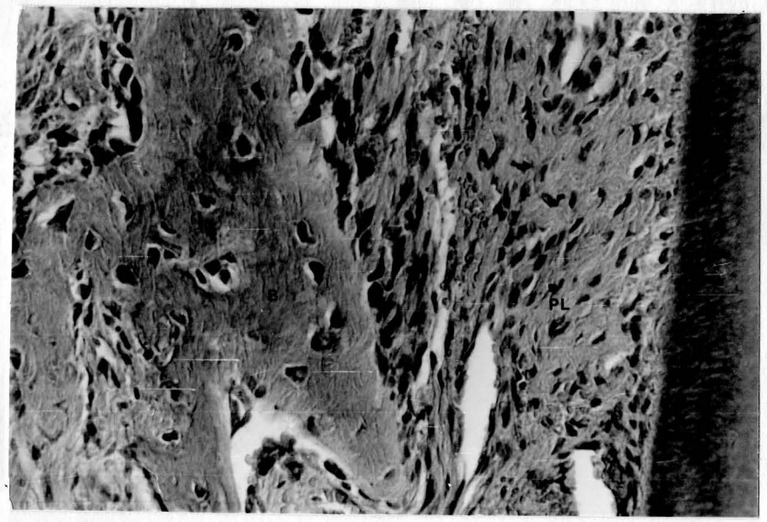

Figure 14

APPROVAL SHEET

The thesis submitted by Timothy P. Reardon, D.D.S. has been read and approved by the following committee:

Dr. Patrick Toto, Professor and Chairman,
Department of Oral Pathology, Loyola

Dr. Milton Braun, Professor and Chairman,
Department of Orthodontics, Loyola

Dr. Michael Kiely, Associate Professor,
Department of Anatomy, Loyola

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval by the committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Oral Biology.

May 7 1976
Date

Director's Signature